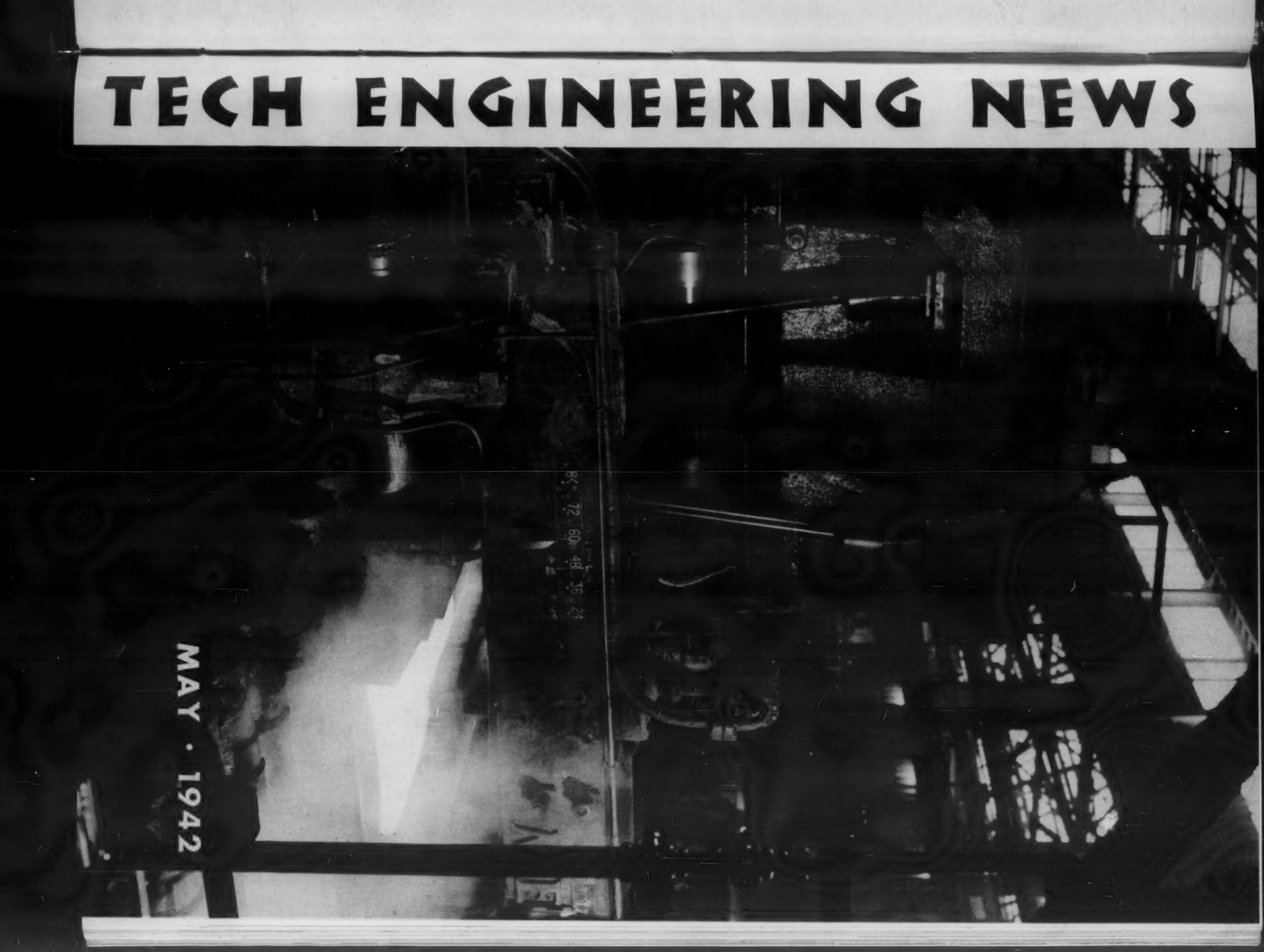
TECH ENGINEERING NEWS



MAY · 1942

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The enormous increase in requirements of molybdenum has necessitated the War Production Board Order M-110, placing molybdenum consumption under allocation control...Our metallurgical research staff is fully engaged in war work. At our mine, mill and converting plant, every effort is being made towards maximum production.

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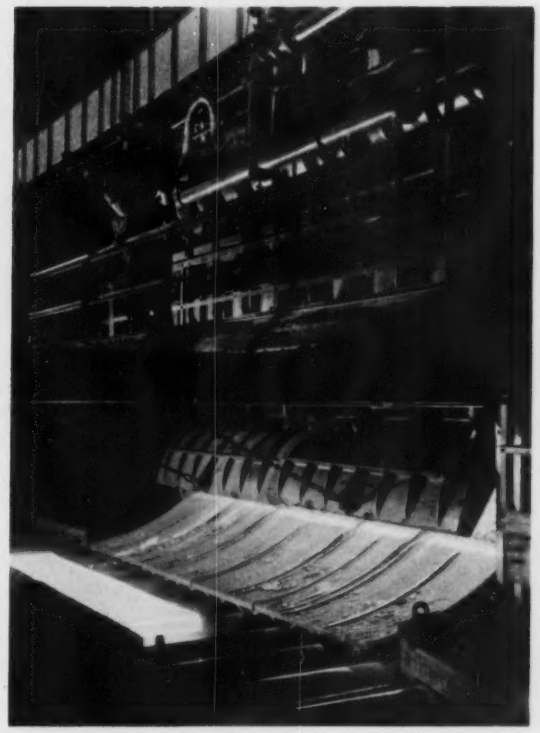
MOLY

TECH ENGINEERING NEWS

MAY · 1942



OUR COVER THIS MONTH

Steel running through a set of walls after being in the slab heating furnace

VOLUME XXIII

NUMBER 4

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.01% IS PASSING

NEW ORE CONCENTRATION METHODS YIELD MORE METALS NECESSARY FOR THE WAR

By RAFAEL R. FEURRING '44

THE conquest of most of the Far East by Japan, and the growing shortage of ships for overseas trade, have dealt a heavy blow to our supplies of essential metals for the war effort. Realizing that this is a mechanized war, in which the reserves of essential metals may be the decisive factor, the government has emphasized again and again the need for an increased home-production.

One look at the facts will convince us of the urgency of the situation. The loss of Malaya, as we all know, has cut off three-fourths of the imports of tin, vital to the production of alloys and solders. We no longer get supplies from the Philippines, where three-fourths of our imports of manganese, and one-quarter of the supply of chromite came from. To the loss of all these metals we must add the fact that because of the increased mortality rate in the submarine campaign, we will have to do without the imports of even those countries which are still open to us.

For more than a year now, the Bureau of Mines has sponsored various researches and experiments designed to increase the development of our own resources and those of the Latin-American countries. On this hunt for metals, and on the ability of the American engineer to find suitable substitutes for unavailable metals, the outcome of the war largely depends. For it is a fact that the Axis, by a fanatic effort to use every available pound of metal at home and in the occupied countries, has almost equalled the potential reserves of the Allies.

One way of increasing our available supply is to go back to the reserves of low-grade ores, which have so far been left untouched due to the excessive costs. There are essentially two parts to the job of exploiting low-grade ores, namely, that of finding them, and the problem of concentrating them to extract the desired metals for the industry. This, in many cases, involves new processes of smelting, of fusing in heavy furnaces, of flotation, and in other instances depends on new chemical discoveries, or on advances in the field of electrolysis.

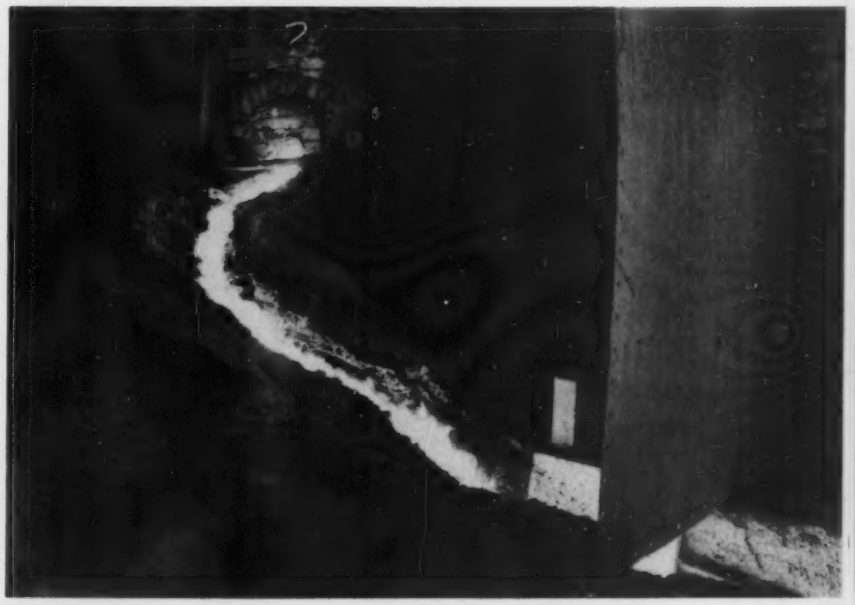
On the other hand, there are metals for which the supply of high-grade ores is potentially sufficient, but where the main effort has to be made in expanding production. An example of this is magnesium.

The strategic metals are manganese, chromium, tungsten, aluminum, nickel, and copper. Tin can be obtained from Bolivia, and there the main problem will be the expansion of present facilities. The real push, in this country, must be made in the search for manganese, chromium, tungsten, and aluminum. Upon our success in making available new resources of those metals will depend the outcome of the struggle.

The mechanical separation of the minerals in an ore by concentration makes it possible to retain the valuable constituents, while discarding relatively cheaply the major part of the unwanted ingredients. Concentration is done either by making use of the different specific gravities of minerals, or by flotation, which consists essentially of floating the particles of one mineral or one group of minerals at the water's surface, making use of surface tension, while leaving the other particles suspended in the water. This is controlled by the addition of various organic and inorganic chemicals in small quantities. Where the specific gravity method is used, there is generally a combination of ball mills and classifiers, which are adjusted so the lighter mineral will rise while the other one sinks.

In the development of our methods of concentration we can measure the progress of our hunt for metals. Thus, the discovery of new tungsten ores in the yellow pine district has greatly increased our supplies of this essential metal, which, through its property of keeping almost diamond hardness at red heat, is indispensable for machine tools. However, the ore would be valueless without a complicated process of concentration, as it includes large amounts of copper, silver, molybdenum, and sulphur. By a first flotation, with the aid of pine oil and xanthate, the molybdenum is floated out; a second flotation, carried out with cresylic acid and sodium oletate, gives a concentrate of ninety per cent

Skimming slag on side near end of furnace



Secondary ball mill grinding circuit and Forrester flotation cells

tungsten. This is thickened, digested with steam and sodium carbonate under pressure, acidified to remove the rest of the molybdenum, and the tungsten finally precipitated with the lime.

This is but one example of our progress in concentration. Chromium, vital for armor plates as the major anti-corrosive agent in stainless steel, and as an essential alloy in steel parts, has recently been discovered as a low-grade ore in Montana and Alaska. Chromium was formerly imported from Turkey, but this must obviously be counted out now. Therefore, on our ability to make the low-grade ores available to the industry depend the supplies of chromium. An interesting example is the Rustless Iron and Steel Corporation's unique process of making stainless steel directly from low-grade chromium ores, running as low as seven per cent chromium, by charging their electric furnaces with iron, stainless steel scrap, iron and chromium oxides.

Manganese is perhaps the most vital metal for our defense effort, because it is needed in almost every steel. Once again the problem is to concentrate it sufficiently in order to make it available to the steel industry. In Nevada experiments are now being made to concentrate twenty per cent manganese oxide up to a sixty-five per cent grade for the use in ferro-manganese alloys. This is done with the aid of a new refining process which separates the manganese from the sulfur dioxide. In Montana the concentrating is done in Fagergren flotation cells, using sodium silicate and a moderate amount of soap. This product is then thickened and fired in a rotating kiln, giving a product which is sixty per cent manganese.

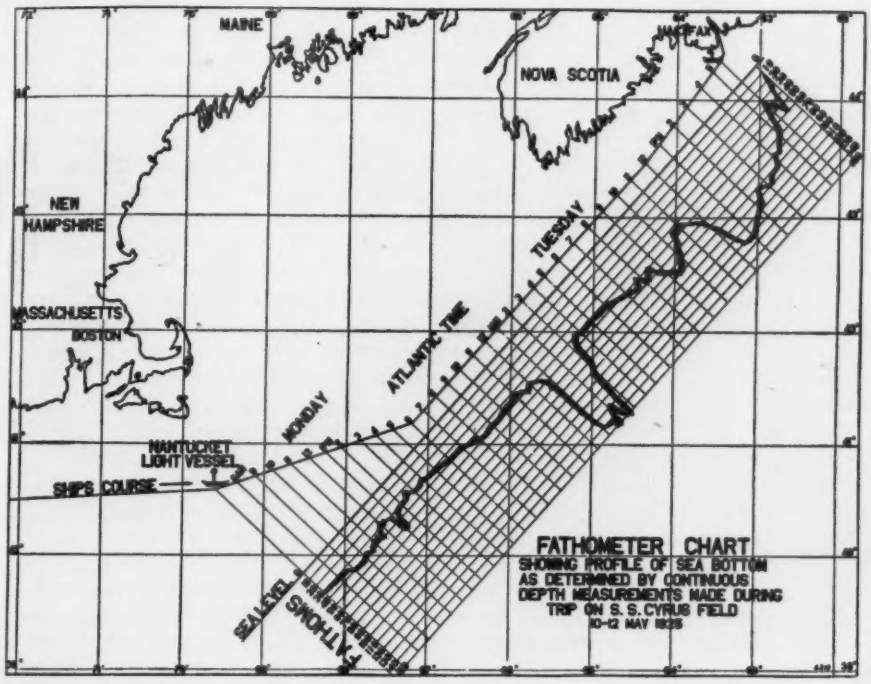
Another way of concentrating minerals is by the electrolytic method, in which very low-grade ores can be used. The Bureau of Mines has used such a process for making 99.9 per cent pure manganese. Other discoveries have yielded a molybdenum concentration from a copper ore assaying as little as .01 per cent molybdenum.

Who of us is unaware of the desperate need for aluminum, so essential to our aircraft industry? Those of us who gave our aluminum pots and other articles to the aluminum collection will undoubtedly be interested to know that we have vast supplies of low-grade aluminum ores, such as alunite, found in the Western States. A process that is now used is the "Kalunite" process, in which aluminum is extracted by means of dilute sulfuric acid, the sulfate being leached off as a potassium sulfate, leaving behind the insoluble aluminum. Another process, designed to extract aluminum from clay, makes use of hydrochloric acid and isopropyl ether to separate the aluminum from iron and silica.

Physical chemistry is an essential tool of the metallurgical engineer. Thus new processes for gaining additional supplies of magnesium involve the reduction of this useful element by carbon at temperatures of 2000° C., and the sudden cooling of the resulting magnesium vapor by a large volume of natural gas, such as hydrogen, which prevents the reversible reaction from taking place. This product is then distilled in a vacuum to give pure magnesium.

From all this we can see that the metallurgists are hard at work trying to make us self-sufficient. If in some cases we have to use extreme measures, which would not be practicable in ordinary times, it is well to remember Donald Nelson's words:

"We may have to require management and labor to adapt themselves to new methods of operation. In such a situation the only thing that could conceivably stop us would be the fact that it was not physically possible to get more ore out of the ground that was already being mined."



SAILING BY SOUND

ECHO FATHOMETER MAKES POSSIBLE NAVIGATION BY OCEAN-BOTTOM LANDMARKS

By B. R. HUBBARD '25

SUBMARINE SIGNAL COMPANY

THE last few decades have witnessed many startling applications of science to simplify the routine tasks of life, and these inventions have nowhere shown themselves more fruitful than in increasing the speed and safety of navigation. In the realm of depth sounding the rapid progress of recent years is all the more noteworthy when compared to the centuries during which the lead and line remained the unchallenged means of measuring ocean depths. The recently developed methods of sounding, which require no mechanical connection with the bottom, represent a radical and brilliant step in man's mastery of the sea.

The features shown on a mariner's chart have a twofold value. First, they point out to the navigator the invisible danger he must avoid and show him the best course to take. Second, they reveal the configuration of the bottom and its physical characteristics so truly that by the use of his sounding apparatus he may fix his position. Because of this fact, great accuracy is required of the hydrographer even when the water is so deep that there is no possible danger of the largest ship afloat touching bottom.

In the early days the only means provided the mariner for measuring the depth was the lead and line. Soundings by this method were difficult to obtain unless the speed of the ship was reduced to eight knots or less and then the reliable maximum depth was about seven fathoms. For greater depths, the ship had to be stopped if the soundings were to be correct. While this was in progress, the ship might be drifting and, in fog, this often was the cause for anxiety.

Soundings were taken as often as possible and in this manner the ship felt her way along. Groping one's way into port in this way may not seem too difficult, but it must be remembered that, unless everything is allowed for properly, the soundings taken at such infrequent intervals may be just the same as those miles away.

As the depth of water increases beyond one hundred fathoms, sounding with a lead becomes increasingly difficult. This method of sounding is based upon the supposition that when the lead sinker reaches the bottom, either a shock is felt or the line becomes slack. It is unreliable for the shock caused by striking the bottom is not communicated to the leadsman through the great depths. Furthermore, the underwater currents have sufficient force to take the line out long after the sinker has reached bottom.

Today, however, the mariner has far better equipment for taking soundings to help him as he approaches land. Modern science has furnished him with an instrument called the Fathometer which provides a simple and reliable means for obtaining a continuous record of the depths over which his ship is passing. These depth measurements can be made under conditions which render all other sounding methods of no avail. While proceeding at normal speed the Fathometer gives the mariner an actual profile of the hills and valleys beneath him.

Everyone knows that a cliff will send back an echo, and that water is a far more nearly perfect medium for transmitting sound than air. It was not until Professor Reginald A. Fessenden created powerful sounds under

water with his submarine oscillator and timed the return of the echo, however, that the marvelous possibilities of echoes were utilized for depth finding.

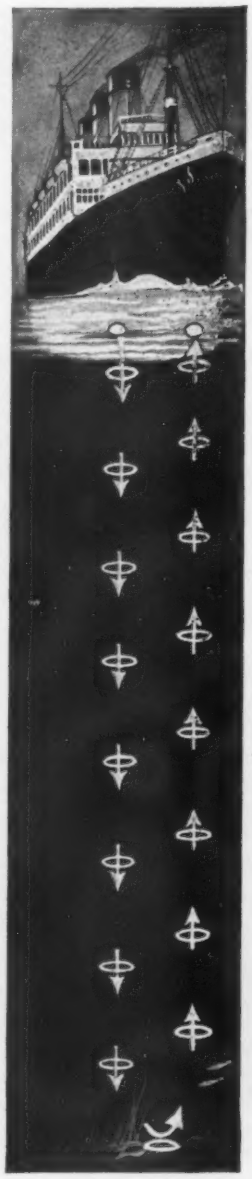
Professor Fessenden's discovery of this new method of depth sounding is linked with the *Titanic* disaster. This appalling catastrophe led him to propose experimenting with his oscillator for the purpose of detecting the presence and proximity of icebergs by means of echoes. In some tests which he made in the winter of 1914 on the Revenue Cutter *Miami* while the latter was on its usual ice patrol off the Grand Banks, Professor Fessenden found that the oscillator could be used not only to detect the presence and nearness of icebergs but also to determine the depth of water. Further developments by Dr. Herbert Grove Dorsey, now of the Coast and Geodetic Survey, in collaboration with the engineers of the Submarine Signal Co., led to the perfection of an extremely accurate device which automatically measures the time required for the sound to reach the bottom of the ocean and return as an echo to the surface. The corresponding depth is indicated visually on the clock-like dial of the Fathometer in the pilot house.

To find the position of the ship with the Fathometer is a comparatively simple matter. The captain, while proceeding on a known compass course, takes a series of soundings of the depth of water under his ship and thus obtains a contour of the bottom of the sea over which he is passing. With this information, he inspects the chart in the neighborhood of the place where he believes himself to be until he finds a line of soundings parallel with his course which corresponds with the contour he has determined from the echo depth soundings. This is a comparatively simple operation and requires very little time. Having determined his position in this manner, he verifies his progress along his course as frequently as necessary by additional soundings. Submarine hills and valleys serve as guides to ships using the Fathometer even better than the visible ones on land for, unlike the visible ones, the submarine landmarks are not obscured by fogs, mist, or darkness.

Since the first demonstration in 1923 before a group of members of the Marine Writers Society on the S.S. *Berkshire* on an offshore voyage from Baltimore to Boston, the Fathometer has become standard navigational equipment on most American vessels. It is a valuable aid in making the new surveys of offshore areas and shoal waters of our rivers and harbors by the government departments that prepare navigational charts.

In recent years the field of usefulness of the Fathometer has been further increased by the development of the echo depth recorder. Two remarkable illustrations of the type of work possible with this Fathometer recorder are shown. When a recording was made in Boston Harbor, the Fathometer record showed not only the true bottom but also the extent of the seaweed growth in the harbor. The second record was taken at the mouth of the Mississippi River during a demonstration given for the United States Army Engineers, December, 1939. The chart taken during this demonstration shows some very interesting and unusual features. This permanent record shows on one contour chart the surface of the water, the depth of the fresh water layer, the depth of the salt water layer just beneath, the depth of the colloidal slush layer, and, finally, the true bottom of the Mississippi River. The most interesting feature is the sloping line which corresponds to the surface of contact between layers of water of two different densities — in this case the descending fresh river water and salt water from the Gulf of Mexico. It will be noted that the river water gently overlies the strata of salt water and does not mix with it. The line of demarcation is quite pronounced.

Thus, depth finding has passed from infancy into manhood, and now the navigator can obtain a permanent record not only of the bottom over which he has passed but also of the various layers of water and deposits on the bottom. Instead of merely finding the depth in an effort to keep from getting into shoal water, he now uses a series of echo depth soundings as a means of identifying his position even in deep water. The Fathometer is responsible for introducing an entirely new technique of navigation — that of "bottom contour navigation."



Sounding with lead and line

POWDER METALLURGY

FAST, NON-SHRINKING MOULDING METHOD SOLVES PRODUCTION PROBLEMS

By R. WALLACE JEVON '44

THE advent of World War II has brought before the public some of the difficulties encountered by industry in its attempt to supply the nation's war needs. Shortages in aluminum, copper, brass, oil, rubber followed one another across the front pages of our newspapers. Some industrial plants shut down for lack of raw materials, while many others were called upon to turn out vast quantities of war machinery. In the second instance many of the government orders required retooling a whole factory and the use of new and entirely different equipment. Many of the transitions were drastic and the problem of production became acute. All possible machine tool equipment was commandeered; old machines were reconditioned and pressed into service; machine shops went on twenty-four-hour shifts. Still machining and fabricating operations are a bottleneck in war productions. These are all foregone facts.

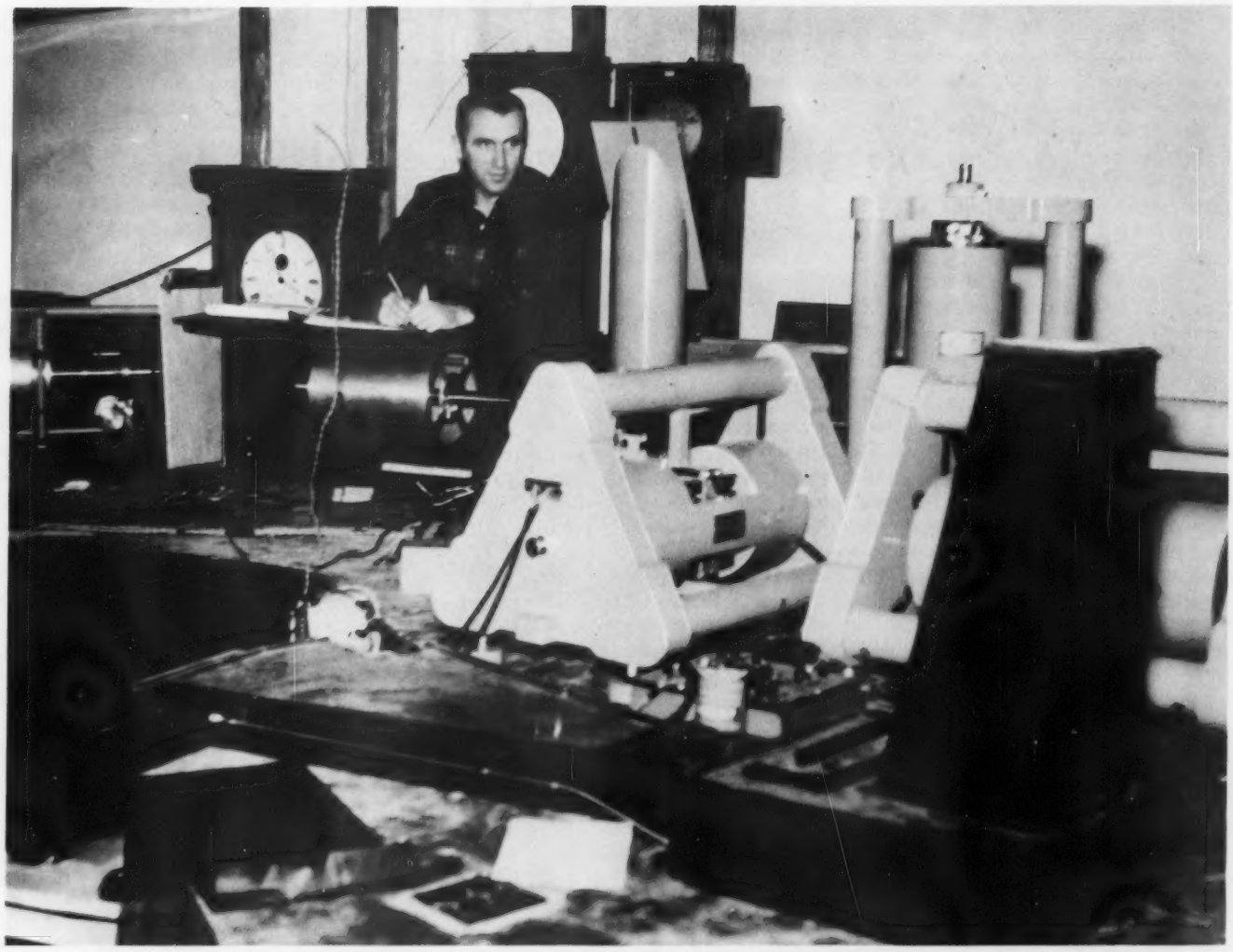
One way around this trouble should certainly be the elimination, as far as possible, of fabricating operations. Castings require a great deal of machining, and while forgings usually present less of a problem to the machinist, they cannot be turned out of the forge with precision great enough to replace machined parts.

New or improved methods of producing accurate parts might solve the problem. Improved foundry techniques have been tried. Moulds have been made more accurate, and improvements have been made in the temperature control of the metals, but there is one kink which foundry men cannot completely beat, and that is shrinkage. Over a year ago a new alloy received much publicity. It had structural properties comparable to those of steel and a negligible coefficient of shrinkage. This material was the copper-berylium alloy which incidentally the public has heard very little of since, probably due to its high cost.

It is in this connection, as a partial answer to the problem of the fast production of accurate machine parts, that powder metallurgy, one of the world's oldest metallurgical techniques, has come to the fore. Powder metallurgy involves the practice of compacting parts from metal powders. The powders are placed in accurate dies and are compacted under terrific pressure (up to one hundred tons per square inch) into the desired form. This process is usually followed by a sintering process, a high temperature heat treatment which fuses any binder used in the powders and welds the metal particles themselves together, giving the piece more desirable properties.

Great improvements have been made in the field of industrial powder metallurgy in the last thirty years until there are now a number of companies devoted entirely to this field. Tungsten lamp filaments, porous machine bearings, brake (*Continued on page 84*)

200 ton hydraulic press used to compact metal powder



Three seismographs mounted to record horizontal, longitudinal, and vertical components of earthquake wave

CATALOGING CATASTROPHES

INCREASED KNOWLEDGE OF THE EARTH AND PREVENTION OF DISASTER ARE GOALS OF SEISMOLOGY

By CARROLL W. BOYCE '45

WHEN the question is asked, "What do you know about seismology?" the typical reaction of the man on the street is a blank look, or, in rare instances, "Oh, you mean earthquakes!" And even "earthquakes" connotes little more than a slight shaking of the earth that usually does no more than rattle dishes, or perhaps it conjures up recollections of the two most famous earthquakes of modern times:

San Francisco, April 18, 1906
Tokyo, September 1, 1923

However exaggerated may be the impression created as to the paucity of knowledge of seismology possessed by the general public, it is a fact that comparatively little is known of this prodigal offspring of the much older science of geology. With this in mind it may be stated at the outset that the province of this discussion will be a general perusal of the entire field of seismology rather than an exhaustive study of any one particular branch.

Perhaps, then, an appraisal of the value of the science would be appropriate first. Until the last few decades the business of recording earth shocks served primarily to determine the intensity and location of the tremors, and through compilation of this data to fix the geographical position of the principal earth faults, these faults being merely the planes along which the internal structure of the earth has rearranged itself so as to produce a marked deviation from the normal con-

tinuity of the earth strata. Determination of these fault planes soon gave the seismologists sufficient data to locate areas of probable future earthquakes and further faulting. Recently the United States Coast and Geodetic Survey has been compiling transcriptions of the various types of "grinding" noises that are recorded through microphones planted in deep wells near fault planes, and the data now at hand enable experts to tell which kinds of sounds presage earthquakes.

One of the first to recognize the value of a comprehensive program for the precise location of earthquakes was John Milne, an Englishman, who spent a large part of his later life in Japan studying quake phenomena. When he first started his work there were no complete data available, but through his efforts a system of international exchange was established which led to the creation, in 1919, of an office which regularly published an organ known as the International Seismological Summary.

Recent refinements, especially in the field of instrumentation, have enabled seismologists to extend the usefulness of their science to things of more practical value. Instruments such as the earthquake analyzer, developed by Professor Arthur C. Ruge of M. I. T., when used in conjunction with the "shaking table" which simulated conditions of an actual shock, have made it possible to obtain better information on the true nature of the destructive forces accompanying earthquakes. Through this increased knowledge it has become possible to study the reactions of various types of structures to the kinds of tremors which are known to be likely to occur in the area. Thus is it seen that science has now found a way to determine what sort of construction renders a building "earthquake proof." Obviously, this ultimate condition of complete immunity from shocks has not been, and perhaps never will be reached, but it is being approached.

Of course there are other varied and valuable applications of the science, but they do not fall within the scope of this discussion, which will restrict itself to the somewhat less technical phases of the subject.

Despite an early interest, seismology as a science has developed only during the last century, especially rapid strides having been made in the last fifty or sixty years. The first known attempt to record earthquakes, however, was almost two thousand years ago: in 132 A.D. a Chinese named Chang Heng devised a recording instrument. It was indeed a simple apparatus, consisting merely of a metal rod held vertical by having its base set in a shallow depression in the ground, thus making it free to fall in any direction. Around the base of this rod were placed eight small but heavy balls, each being held in its proper place by its being set in a slight depression in the earth, just enough to keep it from rolling away during any shaking except that of a violent earthquake, in which case the instrument failed completely to function. The principle of the device was this: the rod would fall in the same direction as the earth was shaking under it, so that the ball which it knocked out of position indicated the direction of the epicenter of the earthquake.

This machine of Chang Heng's may not rightly be called a seismograph, but rather a seismoscope, for it recorded merely the fact that there had been an earthquake and, they thought, told of its approximate direction, while it is the function of the seismograph to record the direction, intensity, and duration of the tremor. By these standards the first instrument worthy of the designation of a seismograph was probably the one used by L. Palmieri at his station on Mount Vesuvius.

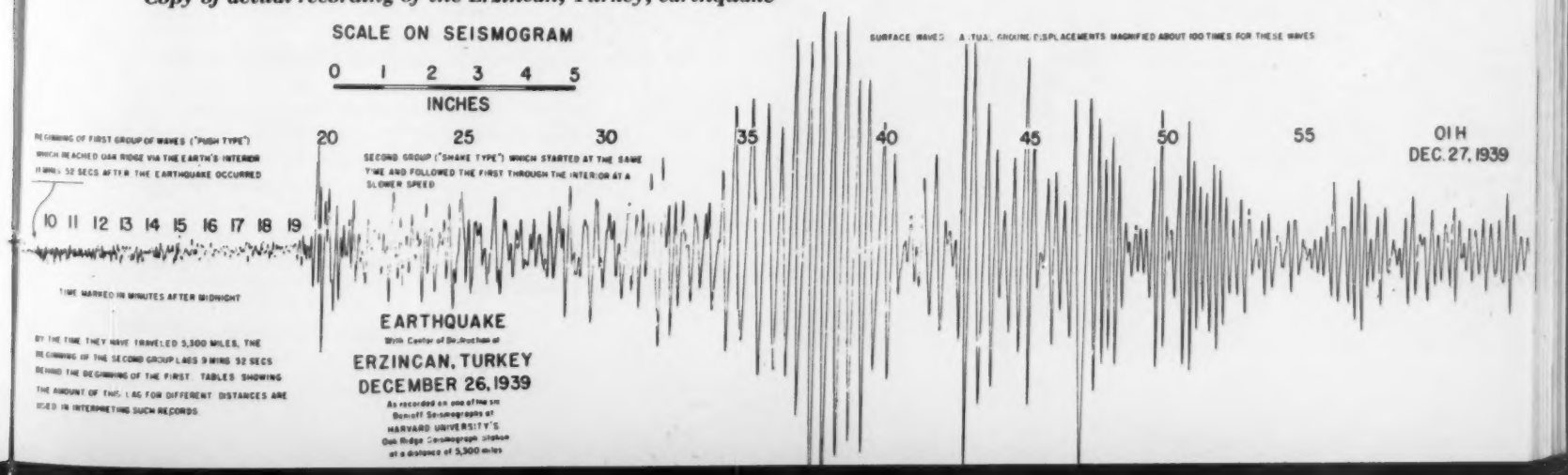
In the last century there have been three types of seismographs whose use has been widespread. The first of these, known as the inverted pendulum, was a very cumbersome instrument that was built by J. D. Forbes in 1842. It consisted of a mass of approximately one ton supported on a vertical column of slightly flexible steel. When the ground shook under this instrument it was set into vibration with a period corresponding to the period of the earth. However, once this period had been established for the pendulum, a change in the period of the earth did not immediately produce a corresponding change in the recorder. In order to obviate this difficulty, Forbes devised a damping apparatus for his seismograph, and although the methods of damping modern instruments differ greatly from that employed by Forbes, they are all directed to the same objective: to return the pendulum to its equilibrium position as soon as the single vibration has ceased, in order that for the following vibration it will be at rest at the start and so may adjust its period to the period of the instantaneous tremor.

In the Forbes machine the damper consisted of a force applied to the mass at its center of percussion by a light steel rod fixed to the ceiling and terminating at the center of percussion. By having this damping rod extend through the ceiling a fulcrum could be obtained that would permit a recording of the movements of the instrument as it was being swayed by the motion of the earth during the quake.

Of the three prominent types of seismographs only the one built by John Milne, about 1880, lacks a damper of some kind. Although the original Milne instrument was recognized as the standard for many years, it was later improved by Professor J. J. Shaw, and became known as the Milne-Shaw seismograph. The radical change in this instrument from the Forbes type is that it is of horizontal pendulum construction.

The mass of the Milne-Shaw recorder is a cylindrical shaped piece of metal weighing about one pound. This bob is fastened on a frame, which is free to swing, that is in the shape of very nearly an isosceles right triangle, the vertex resting on a pivot point that is set into bedrock, the upright leg being supported by a stationary mast and inclined at a very (*Continued on page 86*)

Copy of actual recording of the Erzincan, Turkey, earthquake


SCALE ON SEISMOGRAM
0 1 2 3 4 5
INCHES
SURFACE WAVES ACTUAL GROUND DISPLACEMENTS MAGNIFIED ABOUT 100 TIMES FOR THESE WAVES
BEGINNING OF FIRST GROUP OF WAVES ("PUSH TYPE") WHICH REACHED OAK RIDGE VIA THE EARTH'S INTERIOR 11 MIN. 52 SECS AFTER THE EARTHQUAKE OCCURRED
SECOND GROUP ("SHAKE TYPE") WHICH STARTED AT THE SAME TIME AND FOLLOWED THE FIRST THROUGH THE INTERIOR AT A SLOWER SPEED
20 25 30 35 40 45 50 55
10 11 12 13 14 15 16 17 18 19
TIME MARKED IN MINUTES AFTER MIDNIGHT
01 H
DEC. 27, 1939
BY THE TIME THEY HAVE TRAVELED 5,300 MILES, THE BEGINNING OF THE SECOND GROUP LAGS 9 MINS 52 SECS BEHIND THE BEGINNING OF THE FIRST. TABLES SHOWING THE AMOUNT OF THIS LAG FOR DIFFERENT DISTANCES ARE USED IN INTERPRETING SUCH RECORDS
EARTHQUAKE
With Center of Destruction at
ERZINCAN, TURKEY
DECEMBER 26, 1939
As recorded on one of the six Benioff Seismographs of HARVARD UNIVERSITY'S Oak Ridge Seismograph Station at a distance of 5,300 miles

THE TECH STUDENT

T. E. N. SURVEY REVEALS TIME AVERAGE STUDENT SPENDS ON STUDIES, ACTIVITIES, AND SOCIAL LIFE

By T. E. N. EDITORIAL STAFF

THERE are several very unusual facts that were discovered upon the tabulation of the survey. One of the most interesting is that contrary to belief there is no apparent correlation between grades and the number of hours spent on preparation, as the time spent on preparation is almost constant throughout the different grade groups in the different classes. These hours total about the same as the time recommended by the Institute for homework.

It is also interesting to note that Tech men do not spend all their time working on school work, for a glance at the tabulation shows that there is a large amount spent on many broadening extracurricular activities.

From looking at the figures on the tabulated sheet, we see that as a whole the figures do not seem to have any definite correlation between grade groups and hours spent on the different activities. This is also the case between the activities of the different classes.

Reviewing the questions one by one, we find some interesting results. The sophomores and the juniors seem to spend more time in classes than do the seniors, and the sophomores spend more time than either of the three classes on the preparation of their assignments. It is seen that the juniors spend just about the required time on their work, with the sophomores and seniors spending more than enough on the whole. Reading for further education seems to trail reading for enjoyment by only a few hours. The amount of time spent in the Institute libraries seems to be rather evenly distributed throughout the classes.

Listening to music seemed rather high in some cases, but the explanation lies in the fact that there are a good many men who study with their radios on.

The average number of hours of sleep are not unusually small despite the invariable protest of the Tech men that they are continually tired and have to sleep in classes (or possibly that was included in the answer). Time spent for meals shows a definite trend from little or no time spent for breakfast to about an hour spent on the average for supper. Time spent on social dates was a question which received an assorted number of answers. Some men spent a good portion of their time on social affairs, while others spent none, and there was one who had figured out the hours in a week and placed that as his answer; he was married.

Outside work without pay was not very well represented, and one answer made the sarcastic remark of "suckers."

Bull sessions was a very interesting question, for the number of hours spent on them by some men was really astounding, one man spending as high as fifteen hours a week. As to their topic, the majority of answers could be placed in three categories, women, school, and the war.

As to the amount of time spent on extracurricular activities, most of the upperclassmen would advise the freshmen to spend more time on them than they themselves are actually doing; it seems as though they feel that the freshmen are really having a picnic here and can spend a large amount of time on the activities.

A large percentage of the men belonged to their professional societies, and the ones who did not belong, either did not have an organization for their course, or did not feel that it was worth while.

A few men think that the Institute does not offer the best course in the country in their field, but this seemed to be the case only with about two courses; they were Course 5 and Course 16. Turning to the question of church, it is rather evident that the undergraduates do not go to church very often.

Most of the men that answered the question about exercise thought that walking about the Institute was sufficient to warrant classification in that question, but in that case all of the men do exercise. The swimming pool and the sailing pavilion seemed to be the most popular in the way of facilities for recreation around the Institute.

The magazine wishes to thank all of those who helped us by answering to the best of their ability the questions that were asked.

QUESTION / RATING	Class of 1942					Class of 1943					Class of 1944				
	Below 3	3-3.5	3.5-4	4-4.5	4.5-5	Below 3	3-3.5	3.5-4	4-4.5	4.5-5	Below 3	3-3.5	3.5-4	4-4.5	4.5-5
3. Approximately how do you spend the average week? In considering average take a mean of the first fifteen weeks of school.															
ACTIVITY															
a. Considering cuts, Classes (Including Labs and Lecutres)	25	25	26	22	24	24	27	25	24	28	27	25	23	26	25
b. Assignments	27	24	22	22	24	23	25	23	24	24	24	24	21	26	27
c. Hours more or less than the prescribed amount on assignments.	5	2	1	-2-	-1	5	0	1	-1	1	-3	4	6	2	4
d. Reading for further education in addition to the assignments, including newspapers	2	5	6	3	4	5	4	3	4	4	4	2	4	2	5
e. Amount of time spent in the Institute Library or its branches	3	2	4	1	5	1	2	2	2	2	2	2	2	1	1
f. Reading for enjoyment	3	3	4	3	3	5	2	3	4	2	3	3	3	3	2
g. Listening to music (classical and swing)	4	6	11	4	4	5	5	6	9	4	10	4	8	5	5
h. Sleep	58	59	50	53	56	56	52	54	55	53	52	62	53	56	51
i. Eating (except for banquets) Breakfast	1	2	2	1	2	2	1	2	1	2	2	1	2	1	2
Lunch	2	3	4	2	4	3	3	4	3	3	4	3	3	3	3
Dinner	3	6	7	6	6	4	5	6	6	6	7	6	6	4	5
j. Do you eat alone	2	1	0	1	0	2	1	0	1	0	2	0	0	0	0
... with somebody	7	19	13	4	5	11	17	9	13	5	12	9	13	13	5
k. Social life (dates, dances, etc.)	4	11	8	6	4	5	5	4	5	8	8	5	6	5	5
l. Institute extra-curricula activities	2	5	3	12	8	5	5	5	4	6	5	4	3	7	4
m. Other extra-curricula activities outside the Institute.	1	5	3	1	3	2	1	0	1	2	1	5	2	1	1
n. Work for pay except for cooperative course	4	5	4	2	3	2	5	0	2	5	1	1	1	4	4
o. Outside work without pay	0	1	4	1	3	1	0	1	0	1	0	0	1	1	0
p. Bull sessions	2	10	5	3	4	8	6	2	7	6	7	4	7	5	4
q. Time spent in travel to M.I.T. Trains	3	3	0	0	1	1	0	3	0	0	0	1	2	0	0
Trolleys	0	1	1	0	0	0	0	0	0	0	0	1	1	0	0
Autos	3	2	1	1	1	1	1	0	0	1	1	1	1	17	2
Walking	1	1	1	1	2	1	1	1	1	1	1	1	0	11	1
4. In how many M.I.T. extra curricula activities are you at present engaged?	1	2	2	2	3	2	2	2	2	2	3	1	1	2	2
5. How much time do you advise a freshman to spend on M.I.T. extra-curricula activities?	4	6	8	7	9	8	6	7	6	7	9	6	5	7	4
6. What do you feel is the ideal time for a man in your class to spend in extra-curricula activities? (Assume ability in school work equal to your own)	3	7	8	8	11	6	6	7	6	8	6	5	5	8	6
7. Do you belong to your courses professional society? Yes	4	15	11	3	6	5	9	4	11	4	4	5	4	3	0
No	5	7	2	2	0	8	9	0	3	1	10	4	12	10	5
8. Do you feel that in your course M.I.T. offers the best in the country? Yes	7	16	10	3	5	11	14	4	13	5	9	9	13	9	3
No	2	4	3	2	0	1	4	0	1	0	5	0	0	7	2
10. Do you attend church? Regularly	3	4	2	0	4	1	4	2	3	0	6	1	3	1	1
Occasionally	2	3	2	2	0	2	1	0	1	2	1	4	4	3	1
Seldom	4	15	9	3	2	10	13	2	10	3	7	4	9	9	3
11. Do you take any regular exercise other than Institute athletics? Yes	2	8	11	2	1	8	9	1	5	1	8	6	7	8	3
No	7	14	2	3	5	5	9	3	9	4	6	3	9	5	2
12 Do you avail yourself of: Swimming Pool	6	11	11	3	3	7	13	4	8	4	5	6	11	11	5
Squash Courts	2	2	6	0	0	3	10	1	5	2	1	2	6	2	0
Tennis Courts	4	8	2	1	3	4	6	1	2	2	3	2	5	4	0
Sailing Facilities	1	6	8	2	1	6	8	2	8	2	1	3	8	9	3
13. How much time do you spend in consultation or informal visits with members of the Institute faculty and administration?	5	1	2	2	1	1	1	0	1	0	1	1	0	1	1

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POWDER METALLURGY

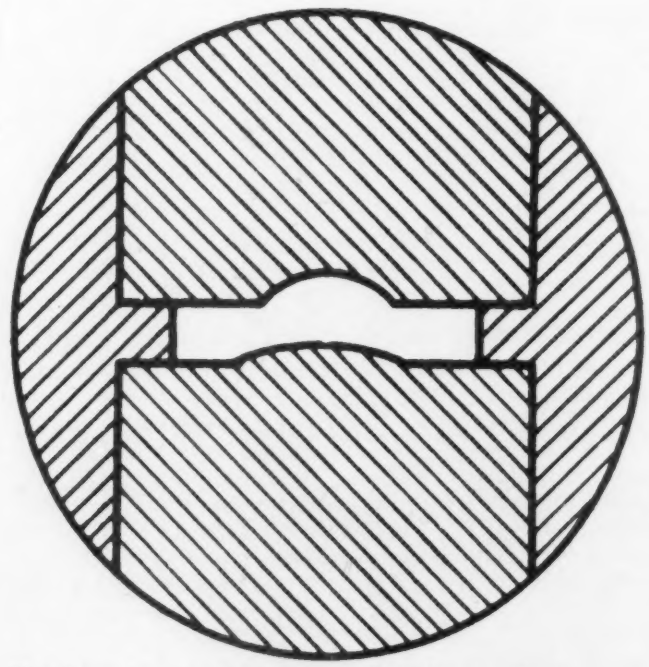
(*Continued from page 79*)

drums, copper tungsten welding rods, tungsten carbide and cemented carbide tool steels, pump gears, cams and magnets are some examples of the powder metallurgist's work. The porous, oil impregnated automobile bearing is a fine proof of what the powder metallurgist can accomplish. Literally millions of porous automobile bearings have been compacted by automatic machines, sintered in atmosphere controlled, continuous operating furnaces, coined to size in automatic presses, and have come out ready to be oiled and put into the machines. How else could the product have been turned out so simply and cheaply?

Powder metallurgy has circumvented the high temperatures required for the reduction of tungsten and similar metals used in hard tool steels. Even diamond impregnated, cemented carbide oil well drill bits and wheel dressers are made by compacting techniques. In addition to accomplishing the production of specialized parts unobtainable by other methods, powder metallurgy is beginning to replace standard practice in the production of simple machine parts. The waste due to machining, which in the case of a cast gear blank may run as high as seventy-five per cent, can be done away with, and a great number of these small parts can be turned out on automatic presses at high speed and low cost in powder metallurgy production.

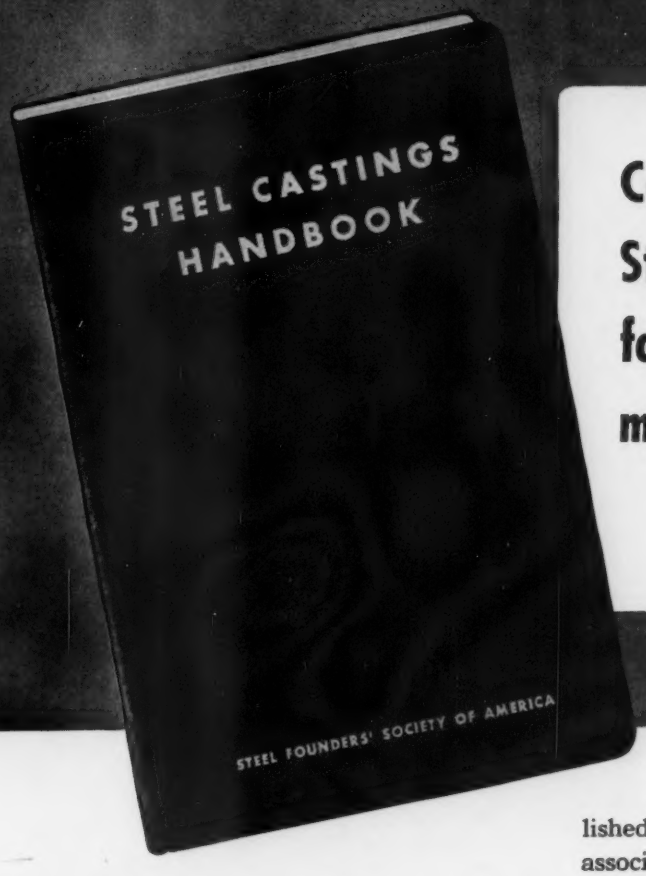
The obvious question brought up by facts like these is, Why hasn't powder metallurgy completely taken over the field and met the shortages threatened by inadequate machine tool production? And the best answer to the question is a look into the powder metallurgy process.

The raw materials for the process are powdered metals of varying particle size. These are obtained mechanically by the atomization of low melting metals and from grinding in mills where practicable for harder metals. Chemical methods, however, are most commonly used for obtaining fine powders. All the molybdenum and tungsten and (*Continued on page 93*)



Metal powder pressing die comprising four sections

SEND FOR THIS NEW BOOK



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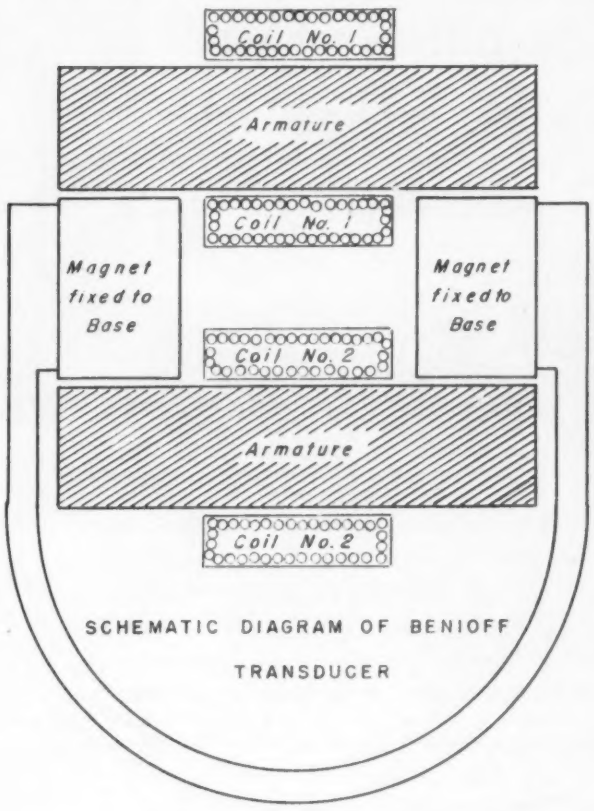
STEEL CASTINGS

CATALOGING CATASTROPHES

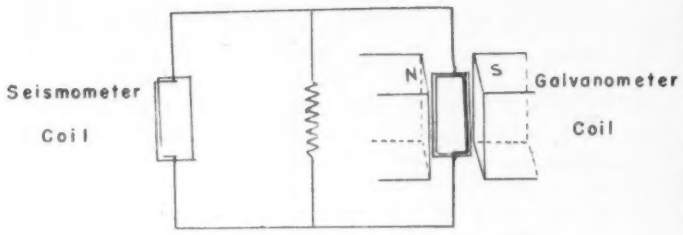
(*Continued from page 81*)

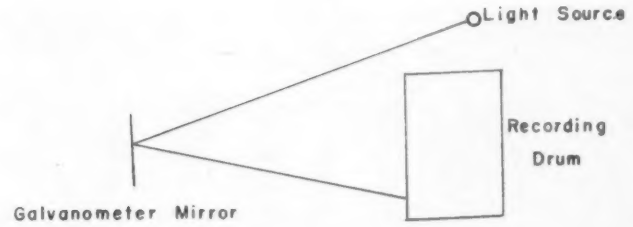
slight angle to the vertical, and the hypotenuse a piece of straight, light wire. The bob, then, is affixed at the extreme end of the free leg, or boom, in such a way that it is permitted to pivot about a vertical axis through the center of one of its ends. When an earthquake causes the mounting to move, a sudden force is applied at right angles to the longitudinal axis of the cylindrical bob, and such a force causes it to rotate not about the axis of support of the entire pendulum but rather about a vertical axis through its own center of percussion. That is to say, what actually happens is that the mass stands still with respect to space while the earth moves.

Due to the fact that a force acting at right angles to the face of the bob is necessary to set the instrument into operation, two of them must be used in order to obtain a complete record. The usual set-up is to have one east-west and another north-south. After the magnitudes have been recorded for each of these two components of the shock waves, it is a fairly simple matter of vector analysis to get a dead reckoning on the direction of the center of the earthquake.



SCHEMATIC DIAGRAM OF BENIOFF TRANSDUCER



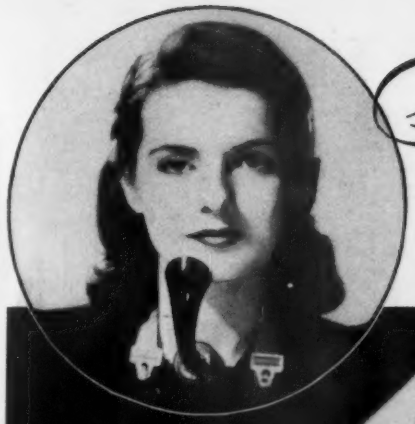


Damping in this case is achieved by simply mounting a permanent magnet in such a way that a copper vane attached to the bob rests in space between its two poles. The permanent record is made by a beam of light that is reflected from a tiny agate mirror on the bob onto a sheet of photographic paper. This arrangement made possible a magnification of actual earth movement up to 150 or 250 times normal. Contrast this with the seven or eight times magnification of the Milne seismograph, in which the recording was by means of a long aluminum rod on paper treated with candle black, or with the magnification of 250,000 permitted by the modern Benioff machine.

This most recent of instruments was built about 1930 by Professor Hugo Benioff of the California Institute of Technology. Its construction is somewhat similar to that of its famous predecessor, the Galitzin seismograph, which like the Benioff, operated on the galvanometric principle. The basic structure of the apparatus is not complicated: a coil is suspended between the poles of a permanent magnet in such a way that when an earthquake sets the machine into vibration the concentration of the lines of flux flowing through the coil is made to vary by the change of distance between the respective poles and the coil as the vibrations proceed. This variation of flux also results in corresponding variations of the amount of induced current; this varying current is then carried to a similar coil on which the number of ampere-turns may be either greater or less to produce the desired magnification. As this coil is made to swing, a beam of light is reflected from a tiny mirror that is mounted on it, then focused down to a pin point of light by the lens through which it passes before reaching the photographic paper on which the permanent record is made. Here, then, is a further opportunity for magnification.

It is also necessary to have a machine that will record the vertical undulations of the earth during a tremor; but of the instruments described, only the Benioff can readily be converted to this type of recording, for the construction of that instrument is such that it may be mounted vertically. The recordings received by this method are as accurate as those of lateral motion. However, the most widely used vertical motion seismograph is probably the Weichert machine. It is simply a spring with a natural period of vibration that is very nearly the same as the period of earthquake waves. That is, it works on the same principle as the Milne-Shaw instrument: the bob on the end of the spring stands still in relation to space while the earth moves up and down.

From the foregoing discussion it is evident that the ideal recording apparatus would be a complete set of three Benioff seismographs; and two such sets are to be found here in New England. One of these sets is owned by Weston University, the other by Harvard University; and it is the Harvard station that is recognized as the center of seismographic research in the United States, and probably in the world. It is usually the Harvard Seismograph Station at Oak (*Continued on page 88*)



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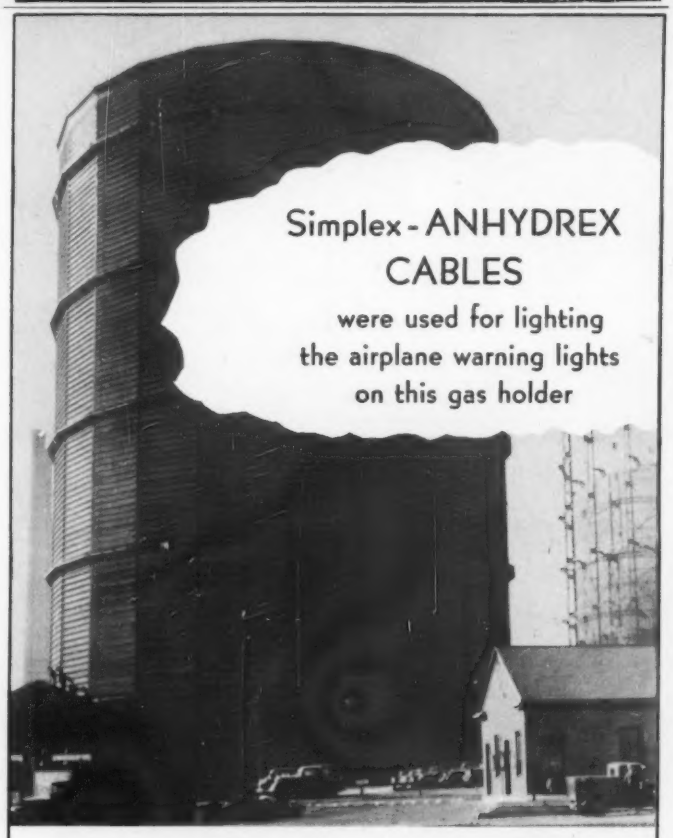

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CATALOGING CATASTROPHES

(*Continued from page 86*)

Ridge (near Harvard, Massachusetts) that the big press services call when they want to determine the geographical extent and intensity of an earthquake that has been reported anywhere in the world; and it is a matter of a very short period of time before Dr. L. Don Leet, who is in charge of the Harvard seismological work, can give them the answer. After the photographic records have been developed, in the dark room that is right in the building with the instruments, it is only minutes before the necessary measurements can be made and computations completed that give a comprehensive picture of the location, intensity and duration of the quake.

At this piht something needs to be said about how these determinations are made; but in order to have an understanding of the principles involved, the causes and methods of propagation of earthquakes must first be examined. One of the main causes of earthquakes, especially those of great violence, is faulting in the earth, and for present purposes it will be sufficient to consider that case only. When faulting occurs it means that one of two things has occurred: that internal pressures far beneath the surface have built up along the fracture planes in the earth's crust to such an extent that they have forced portions of the crust near these fractures to move upward in order to relieve the pressure, or that the accumulating forces are near the surface and have a readjustment of parts of the crust in a downward direction. In some cases the (*Continued on page 90*)

"TO PROVIDE FOR THE COMMON DEFENSE, TO PROMOTE THE GENERAL WELFARE"

Bad medicine for big bombers

ONE WAY to spoil a bomber's aim is to hang a curtain of steel over your ship and dare him to come down through it. To get that curtain of steel up there requires quick-firing, flexible guns.

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Westinghouse

"An Engineer's Company," Westinghouse Electric & Manufacturing Company, Pittsburgh, Pa.

CATALOGING CATASTROPHES

(*Continued from page 88*)

faulting is close enough to the surface or the arrangement of the fracture is such that the crustal rearrangement extends to the surface. It is such things as this that cause fissures to be opened up in the ground, or that cause surface displacements such as those that were known to take place in Sagami Bay during the Japanese quake of 1923. According to the Encyclopedia Britannica there are spots on the floor of Sagami Bay that were known to suffer a depression from previous depths of 400 fathoms, while others became 250 fathoms shallower, and the entire island of Oshima was shifted 12 feet five inches in a northerly direction at the same time that it was rising five feet four inches above its previous water line! It is, however, probable that such fantastic figures are not so much the result of faulting as of the landslides which followed the shocks.

Although such violent surface reactions are the exception rather than the rule, the momentum of the tremendous mass of earth involved in a fault movement is sufficient to set the entire earth vibrating. These vibrations are transmitted in very much the same way as sound is transmitted through any solid medium, except at a much greater velocity; and two kinds of waves, transverse and longitudinal, are propagated from the focus of the quake, to travel through the earth at different velocities. Thus it is necessary only to measure the lapse in time from the instant at which the first of the primary waves is recorded until the first of the secondary waves is received in order to determine the distance from the recording seismograph to the center of the quake. (See accompanying photograph of seismographic record of an actual earthquake.)

In connection with propagation of elastic waves it should be mentioned that there are several phases of subject on which the existing information is insufficient to enable seismologists to draw any positive conclusions, and along those lines research is continuing apace.

During the series of shocks that were felt in New England a few years ago Dr. Leet organized a network of stations that operated with Benioff seismographs: three each at Harvard and Weston, and single machines at Williams, Fordham, M. I. T. and Ottawa, Canada. By means of the observations made at the time it was definitely established that the compressional waves that travel 21 miles below the surface have a velocity of 8.4 kilometers a second, instead of 7.7 as previously supposed, a difference amounting to some 1500 miles an hour.

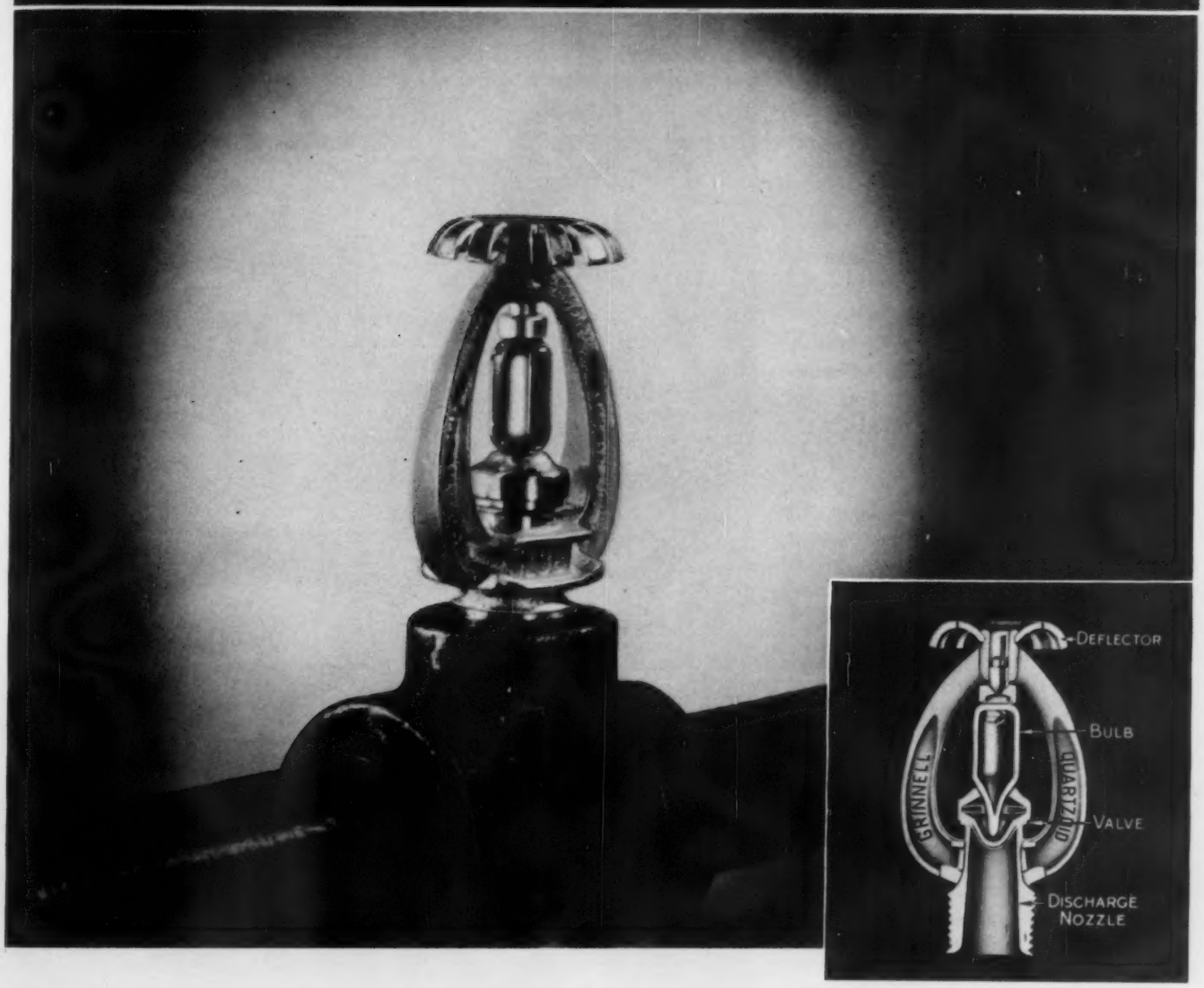
Particularly in evidence since the development of a machine as delicate as the Benioff has been the so-called microseism which manifests itself in the form of a continuous series of vibrations of comparatively small amplitude. Although at most times these microseisms do not seriously interfere with the recording of regular shocks, at certain times of the year, especially in the fall and winter, they are of such violence that the magnifying power of the recorder has to be cut to about one-third its norma! 250,000 times. Little is known as to the exact cause of these disturbances, but some clue as to their origin may be found in the fact that storms pounding the coast cause an almost identical pattern of vibrations to be recorded.

Until very recently it was thought that there were just four kinds of elastic waves, two that travel in the earth and two others that are propagated along the surface, but in the last two years evidence has come to light that tends to establish the existence of a fifth kind of wave, the exact nature of which has not yet been definitely ascertained. This new type, known as the "Leet wave," was first found to exist by studying the records of artificial earthquakes, such as those produced by quarry blasts. After finding evidence of the new wave in the artificial quakes, Dr. Leet was able to determine that this kind of wave was present also in natural tremors. With the coöperation of other seismologists it was found that at certain distances from the epicenter of a shock the "Leet wave" is the same as the ordinary shear wave. This information led rapidly to the discovery that there is no such thing as a pure shear wave in earthquake propagation; rather, that the characteristics of the shear wave change as it progresses through the earth in such a way that at times it is compressional, at other times it is a "coupled" wave, and for only a small percentage of the time is it a true shear wave.

Just as the spectroscope has vastly increased our knowledge of the sun and stars, so today is the seismograph increasing our knowledge of the earth. By methods that are in use today, and methods that will be devised tomorrow, the seismologist is finding out how the earth is put together, and why; he is finding out just what are the destructive forces that are active during an earthquake, and how to combat them before the earthquake happens. In other words, the seismologists, like the men in all branches of science, are at work on their contribution toward making the world a better place to live in.

Dr. L. Don Leet adjusting one of the earthquake recorders at the Harvard Seismograph Station

The little glass fireman that draws no pay . . .



TAKE a good look at this picture. For without a ladder you seldom get a close-up of a sprinkler head.

This one is said to be the last word—so reliable that industries which equip their buildings with this little "fireman" obtain low insurance rates. Users say it pays for itself.

When the heat of a fire reaches a certain temperature, the little "Quartzoid" bulb you see in the sprinkler head is shattered by expanding liquid inside it. A valve is thus released, and water is directed onto the fire.

For the engineer, there's more to that little bulb than meets the eye. For one thing, it replaces alloys formerly used. For another. it shows how glass can now be made into accurate mechanical parts. The bulb must shatter at a specific temperature. And it must shatter completely, with no splinters to hinder valve action. Too, it must fit its hardware exactly. So it's up to Corning to supply glass free from weakening flaws and to hold wall thickness and O.D. to the small tolerances that can make or break the efficiency of a sprinkler head.

Fussy? Sure. But fussy and tough jobs are stock in trade at Corning. Did you know for instance that Corning makes a light globe that also protects industry because, unlike the "Quartzoid" bulb, it will *not* shatter? That Corning has developed industrial glasses to withstand heat that turns metals to liquid? Or that glass springs from Corning will outlast metals in fatigue tests?

These few examples give you an inkling of the growing usefulness of glass in these days of material shortages. No wonder engineers with urgent problems say "Ask Corning." Corning Glass Works, Corning, N.Y.

CORNING
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Research in Glass

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BACKBONE FOR STEEL!

Chromium, the element that imparts precious color to rubies, imparts something more precious to steel. It gives steel incredible hardness and resistance to heat and corrosion. It makes steel strong, yet ductile and shock-resistant.

Chromium is the key that has opened — and is still opening — great new fields of application for steel. Without chromium, the whole wonderful series of *stainless steels* would not have been possible. From tarnish-free tableware to corrosion-resistant chemical equipment . . . from strong, lightweight truck bodies to streamlined trains and airplanes . . . from heat-defiant boiler tubes to high-temperature steam turbines . . . chromium has made possible a *steel* with properties of the *noble metals.*

But the stainless steels are only one great contribution of chromium. This element has also helped to provide hard, shock-resistant armor plate and armor-piercing projectiles; long-wearing engine valves; strong, tough gears, tools, ball bearings, car trucks, shafts, springs, and dies; and hundreds of other improved articles.

We do not make steel of any kind. But for over 35 years, we have made ferro-alloys and alloying metals used in steel-making. Among these are chromium, silicon, manganese, vanadium, tungsten, zirconium, columbium, and calcium.

It was our research and development that made the low-carbon grades of ferro-chromium available commercially. Without these, production of a majority of the stainless steels would have been impracticable. Inquiries about stainless and other alloy steels — their manufacture, fabrication, and use — are cordially invited.

The progress made by Electro Metallurgical Company in the manufacture and use of ferro-alloys and in the development of alloy steels has been greatly facilitated by metallurgical research in the laboratories of Electro Metallurgical Company and Union Carbide Company; by the advances in electric furnace electrodes and techniques of National Carbon Company, Inc.; and by the broad experience in the production, fabrication, and treatment of metals of Haynes Stellite Company and The Linde Air Products Company. All of these companies are Units of Union Carbide and Carbon Corporation.

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Unit of Union Carbide and Carbon Corporation

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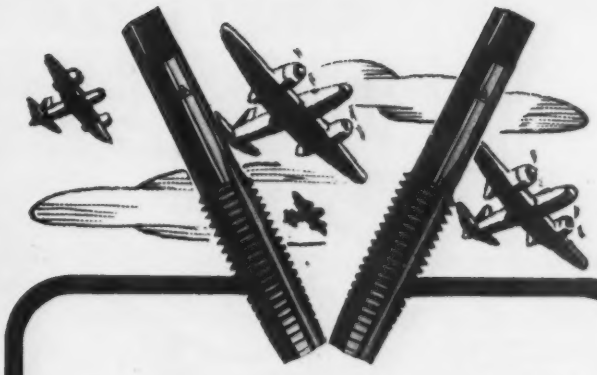

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"Greenfield" Taps, Dies and Gages are helping to build practically every plane and engine used by our Army and Navy.

70 years of practical experience enable these tools to meet Uncle Sam's most rigid requirements. That experience is one reason why skilled workers and production men always have confidence in *"Greenfield"* tools.

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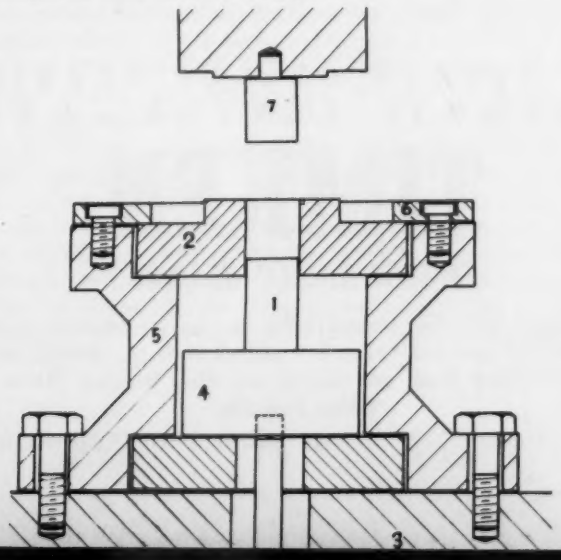
POWDER METALLURGY

(Continued from page 84)

much of the copper, nickel, cobalt, and iron used are obtained by the reduction of the metallic oxide with hydrogen or some other reducing agent. Then too, electrolytic methods are responsible for tons of copper powder. The next step in the production of a compact is one which gives powder metallurgy a decided advantage over molten metal processing. The powders can be mixed in exact proportions and the alloys produced will be as pure as the powders from which they were formed, provided sintering is carried out in a reducing atmosphere and for a sufficiently long time (sometimes several hours). Another interesting point is the fact that the mixed powders may contain materials other than metals. Some of these materials volatilize to give porosity as in the case of bearings. Other powders contain binders which fuse and hold the other constituents together as cobalt does in many of its compacted alloys. A third case is the production of diamond carbide drills and tungsten carbide tools which are cemented together by the carbides.

The next step in the process of producing a compact consists of compressing the mixed powders in a tool steel die often necessarily complicated and of accurate design and finish. The accompanying drawing is of a typical die. The press which holds the die is automatically fed with powders from *(Continued on page 95)*

Technique of setting die in the press



Key to parts of press:

1. *Bottom punch*
2. *Die*
3. *Table of the press*
4. *Ram (pressure transmitting part)*
5. *Die adapter*
6. *Clamp*
7. *Top punch*
8. *Ejector rod*

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Victory for the United Nations in the war will, to a great extent, be a victory for American engineering and incidentally, for Timken Tapered Roller Bearings.

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Among other things you will find—as thousands of experienced engineers already have proved—a thorough knowledge of Timken Bearings and their application as useful as your slip stick. It will enable you to meet every bearing requirement completely and soundly. We will be glad to help you with your bearing problems at any time.

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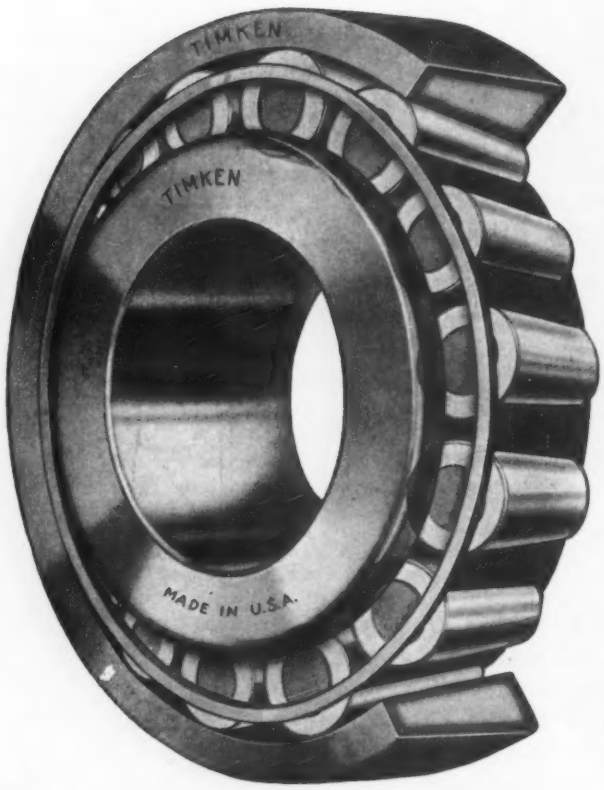

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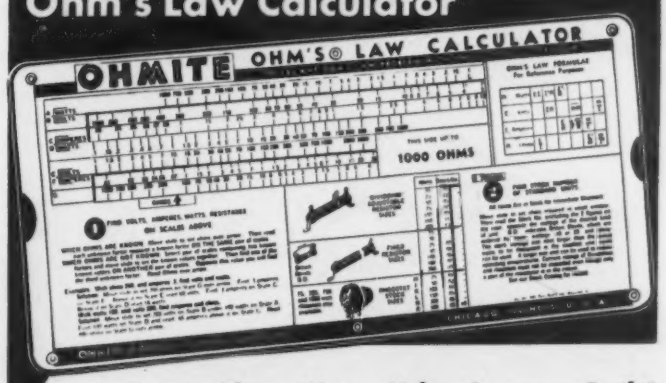
POWDER METALLURGY

(*Continued from page 93*)

hoppers and the compacts are ejected from the press at rates in some cases approaching the speed of fire of modern automatic firearms. In some cases the compact is the finished product, but more often further heat treating is necessary. In many cases of sintering, virtual alloying takes place by the solid diffusion of the particles and the final product has the appearance and properties of a fused metal part.

The limitations of the process depend upon the availability and cost of materials together with the inherent difficulties involved in the compacting of powders which will not flow around corners. Parts should be symmetrical and contain no reentrant angles which cannot be overcome by coring or parted patterns as in the foundry. The high pressures required have given rise to many design problems in the press and the die itself which must conform to close tolerances even under continuous operation. This matter of tolerance can be controlled to the order of .001 of an inch and if greater accuracy is required the part will have to be coined and probably machined to exact size. The high pressures and their resulting design problems have limited the powder metallurgist to the production of comparatively small parts, preferably less than six inches in diameter and under three-quarters of an inch thick. Larger parts, however, are being practically made by compacting methods but at the sacrifice of speed and economy. It is the job of engineers to overcome these obstacles, for industrial powder metallurgy has accomplished a great deal in its short rise to prominence and seems to be pointing one way to beat one of the biggest bottlenecks in our war effort.

Get this Handy OHMITE
Ohm's Law Calculator



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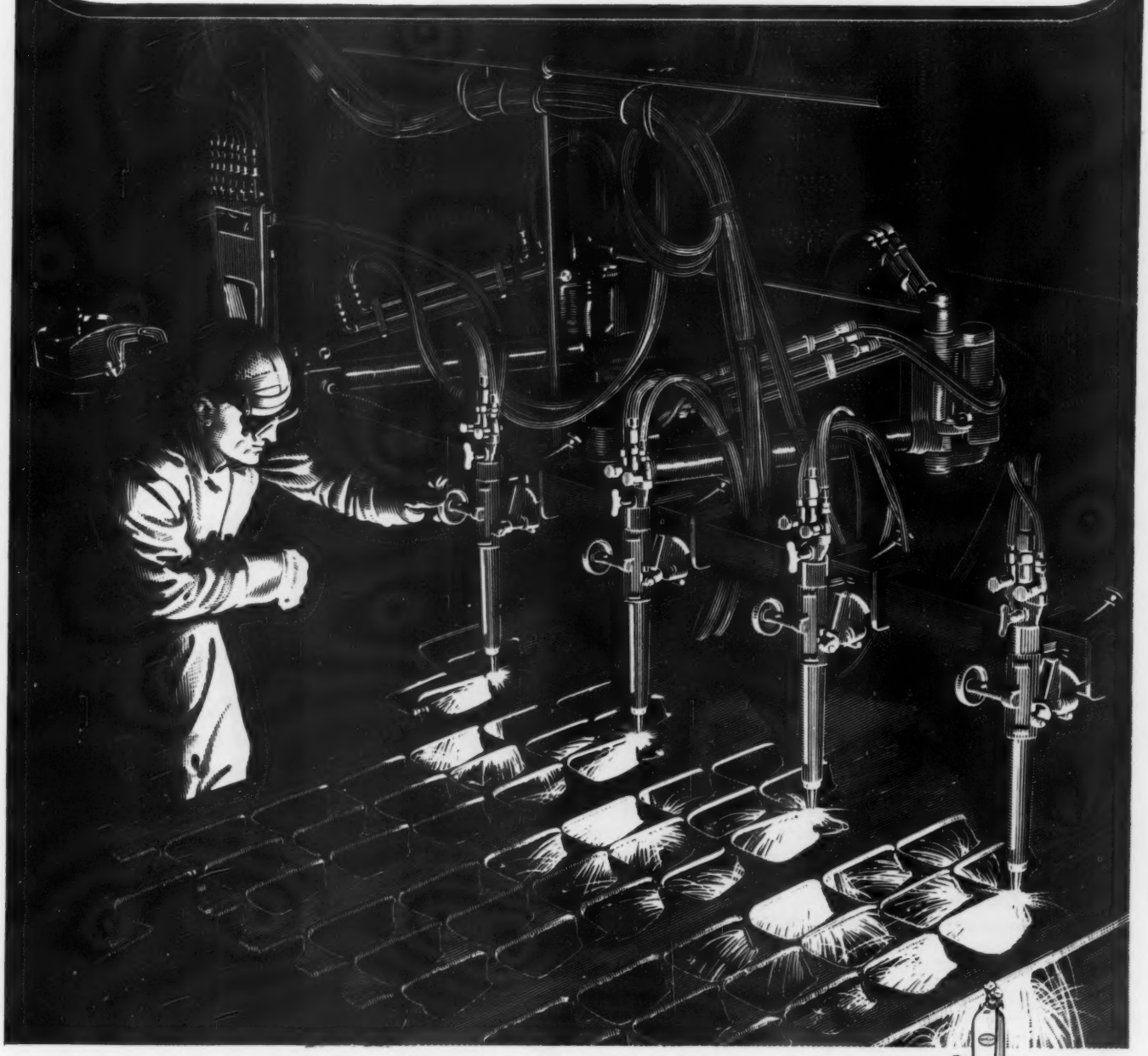

EACH hour is worth ten in production time when steel plate for our machines, guns, tanks and ships are multiple flame cut by the Airco Oxy-acetylene Flame. Slicing its way through steel and iron, this white hot flame has revolutionized metal fabrication by providing a swift, accurate, economical method of shaping sheets, forgings, castings, structures and pipe. Size and shape which can be cut is practically limitless. A single piece or hundreds of identical pieces can be shaped to amazingly close tolerances. Changes in design require only new blueprints or templets to guide the torch.

Other defense jobs being done by this versatile metal working tool include hardening steel to any degree and depth; welding two or more metal parts into a strong, homogeneous unit; machining metals with unrivaled speed, and cleaning and dehydrating metal surfaces for long lasting paint jobs. To insure greatest speed, efficiency and economy in applying the Airco Oxy-acetylene Flame to defense production, Air Reduction offers industry the cooperation of a complete engineering staff.

To better acquaint you with the many things that this modern production tool does better we have published "Airco in the News", a pictorial review in book form. Write for a copy.

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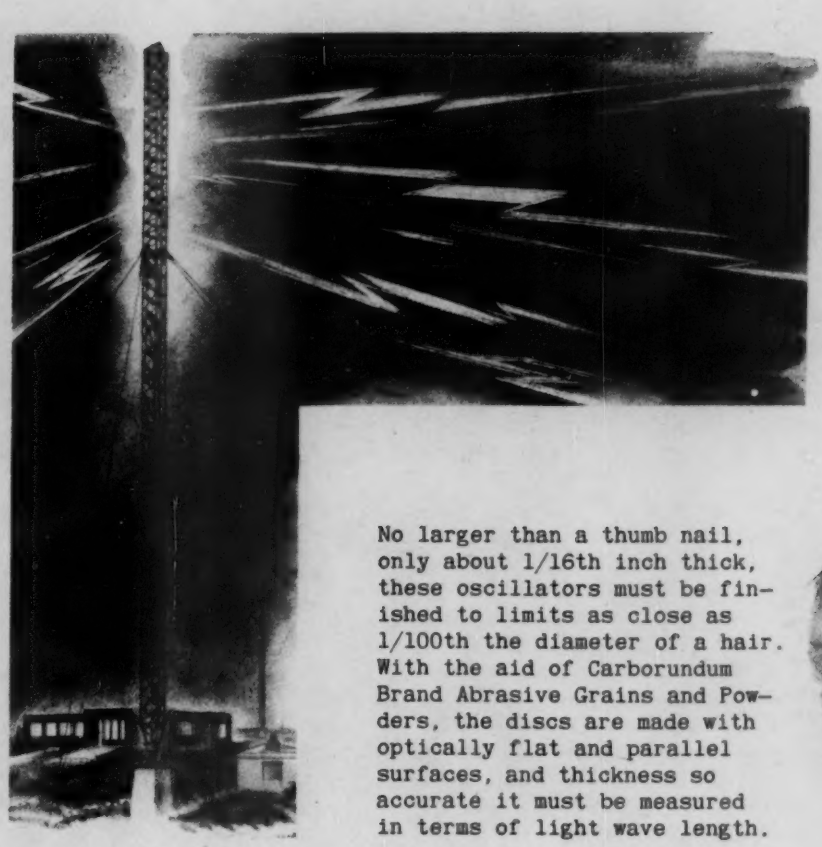
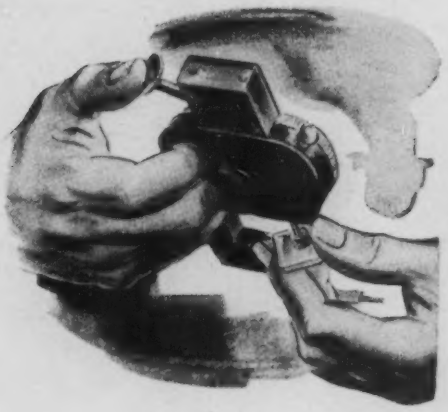


Doubletalk? No, it's how radio would sound if stations couldn't be kept on their assigned frequencies. The problem was licked once and for all when engineers discovered how to regulate radio frequencies with a tiny disc of quartz crystal, the thickness of which governs the length of the waves. Precision cutting, grinding and finishing of the quartz, a process Carborundum helped pioneer, makes today's accurate control possible.



No larger than a thumb nail, only about 1/16th inch thick, these oscillators must be finished to limits as close as 1/100th the diameter of a hair. With the aid of Carborundum Brand Abrasive Grains and Powders, the discs are made with optically flat and parallel surfaces, and thickness so accurate it must be measured in terms of light wave length.

In the development of many modern aids to living, abrasives have played a vital part. And Carborundum skill and knowledge have made much of this progress possible. These facilities will be at your disposal no matter what industry you go into. The Carborundum Company, Niagara Falls, New York.

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G-E Campus News

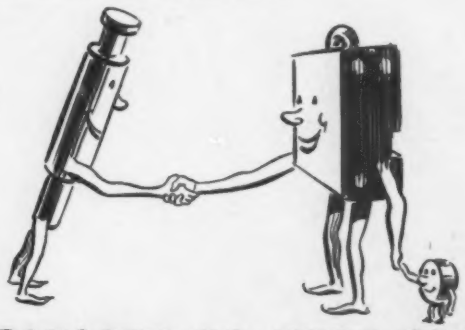
AU-TUBE-IOGRAPHY

GENERAL ELECTRIC'S Radio and Television Department, in its new Radio News Program with Frazier Hunt, is telling the story of electronics to a nation at war—a war in which electronics itself is one of our most powerful tools.

For electronics—the youthful science that embraces all the varied applications of electron tubes—is going into war not only on the front, but behind the front, where it is today revolutionizing many industrial practices.

Unique about this thrice-weekly broadcast (Tuesday, Thursday, and Saturday) is the fact that G.E. is using an electronic device, radio, to carry the story of electronics to America.

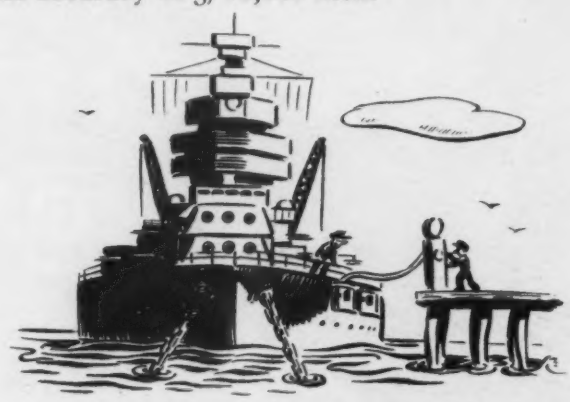
In addition to 51 stations of the Columbia Broadcasting System, G.E. is using the first network of FM stations ever to carry a regular series of broadcasts.



"PLEASED TO MEET YOU"

IT USED to take General Electric 18 months to build one of the great 275-ton machines that cut low-speed gears for cargo-ship propulsion sets. Today that time has been halved by farming out the construction of parts to dozens of subcontractors.

Major parts of the machines come together for assembly from 12 separate subcontractors in five states; miscellaneous smaller parts come from 38 firms in seven states. Jobs of casting, annealing, and machining involve, besides foundries and steel companies, a Navy yard, shipbuilding yards, a locomotive company, and a maker of steel safes. Co-ordinating and checking all these widespread activities is a major achievement in itself, since the finished machine has to be precise enough to cut gears with an accuracy of 3/10,000 inch.



"FILL HER UP!"

BECAUSE the ocean isn't equipped with filling stations every few miles, naval vessels must carry enough fuel for long voyages. And because finding storage room aboard for this fuel is a serious design problem, anything which cuts down fuel consumption is a a great advantage.

Most naval ships today are driven by steam turbines connected to the propeller shafts, through reduction gears. And turbine engineers, working with the Navy, have pioneered in the use of higher steam pressures and temperatures—producing turbines of such improved efficiency that in modern ships the fuel consumption per horsepower is from 25 to 40 per cent lower than in vessels of the same type used during the first World War. Thus it has been possible to design ships with greater cruising radius for the same amount of fuel oil, or with more armor and guns for the same over-all weight of the ship.

GENERAL ELECTRIC

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